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Effect of carbon regulations on the financial technological development: Russian and European companies' adaptation strategies

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Abstract. The plans announced by the European Union to impose a carbon fee by 2022 on commodities purchased from both European and external manufacturers make it increasingly relevant to examine the adaptation of Russian and European companies to low-carbon requirements. The article aims to assess the financial technological costs, technological achievements and energy transition risks for enterprises in Russia and the EU. Theoretical approaches to analyzing technological effects of carbon requirements on enterprises constitute the methodological framework of the study. The research methods of comparative qualitative and quantitative analysis were used in relation to technologies introduced by European and Russian large companies, reached values and dynamics of the carbon footprint in manufacturing, energy consumption, the percentage of renewable energy, the size of costs and investments, projected parameters of traditional energy, the EU plans, and the cost price of alternative energy. The empirical evidence includes public reports of European and Russian exporting companies affected by the carbon fee introduction, as well as microeconomic statistics. The analysis showed that both European and Russian major exporters by the end of 2021 had already initiated certain efforts to reduce their carbon footprint and achieved satisfactory outcomes in this area. In some cases, the Russian companies were even more successful than the European ones, but in general they lagged behind. However, expenses of the European companies are more significant, and energy transition risks for them are higher, which significantly reduces the dividend received by the leader. We propose recommendations to protect Russian business, including export-oriented one, from excessive costs incurred in the development of low-carbon energy. These recommendations can be of use for authorities when implementing industrial policy.

Keywords: industrial policy; EU carbon regulations; technological advances; low-carbon development; energy transition risks; Russia; the European Union.

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Влияние углеродных требований на финансово-технологическое развитие: особенности адаптации российских и европейских компаний

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Аннотация. Анонсирование Евросоюзом к 2022 г. планов взимания платы за углеродный след продукции, закупаемой как у европейских, так и у внешних производителей, актуализирует изучение особенностей адаптации российского и европейского бизнеса к низкоуглеродным требованиям. Статья посвящена оценке финансово-технологических издержек, технологических достижений и рисков энергоперехода для российских и европейских компаний. Методологическую базу исследования составили теоретические подходы к анализу технологических последствий углеродных требований для бизнеса. Использовались методы компаративного качественного и количественного анализа в отношении внедрявшихся европейскими и российскими крупными компаниями технологий, достигнутых значений и динамики углеродного следа производства, энергопотребления, доли возобновляемой энергии, размеров затрат и инвестиций, прогнозных параметров традиционной энергетики, планов Евросоюза и себестоимости альтернативной энергии. Информационной базой послужила открытая отчетность компаний – экспортеров Евросоюза и России в отраслях, затронутых углеродным сбором, а также макроэкономическая статистика. Анализ показал, что как европейские, так и российские крупные экспортеры к концу 2021 г. прилагали усилия к снижению углеродного следа и имели достижения в этой сфере. В ряде случаев российские компании оказывались даже успешнее европейских, но в целом им уступали. Однако и издержки европейских компаний значительнее, а риски энергоперехода для них выше, что существенно снижает получение лидером желаемого дивиденда. Предложены рекомендации по защите российского бизнеса, в том числе экспортно ориентированного, от чрезмерных затрат в области развития низкоуглеродной энергетики. Данные рекомендации могут быть использованы органами власти при реализации промышленной политики.

Ключевые слова: промышленная политика; углеродные требования Евросоюза; технологические достижения; низкоуглеродное развитие; риски энергоперехода; Россия; Европейский союз.

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INTRODUCTION

The carbon emissions regulations of the European Union (EU), as a buyer dictating its own terms, resulted in 2021 in the announcement of the Green Deal, a plan aimed at introducing CO_2 emission costs, which partially affected imports to the EU from Russia, especially of polluting goods. First of all, this applied to goods, whose production was the most carbon intensive (i.e., having the biggest carbon footprint) and at most significant risk of carbon leakage, such as steel, cement, aluminium, electricity, and nitrogen fertilizers. At the end of 2022, it was agreed that the Carbon Border Adjustment Mechanism (CBAM) would enter into application in its transitional phase on 1 October 2023[1] instead of 2026, as previously planned. If the EU continues to import Russian goods, this would reduce either Russian exporters' profits or their competitiveness compared to other producers.

The decision to impose a carbon fee is due to the fact that European producers already bear the costs associated with free carbon dioxide emission quotas; if they emit more than this amount, they must purchase the excess quota. As of 6 April 2023, the price of EU Carbon Permits on the European Union's carbon market equaled 101.25 euros per tonne[2]. The accelerated introduction of carbon regulations by the EU is aimed at solving not so much an environmental, but a geo-economic problem, which is to obtain energy in a less costly way than importing Russian energy sources, i.e., from renewable sources, such as wind, sunlight and hydrogen. If successful, the EU will gain energy independence, and energy will be generated with the minimum amount of fossil fuels and as renewable as possible. Modernization in this field is happening in parallel with the transition to the sixth technological mode [Glazyev, 2022, p. 95]. However, the costs and risks of this transition are very high.

By 2022, when the EU enforced severe economic sanctions against Russia, it was several years since both European and Russian companies had been forced to master technologies for reducing carbon emissions in accordance with international climate agreements. These sanctions mitigated the carbon fee problem for the Russian business, while setting the task of import substitution for the country's economy. Against the backdrop of the EU restrictive measures, business revenues in European countries decreased, and low-carbon production became too expensive. The above increases the interest in companies introducing low-carbon technologies and the consequences they face.

The paper is centered on a comparative assessment of the financial and technological costs, technological advances and risks of the energy transition of Russian and European businesses, while adapting to low-carbon requirements. The results of this assessment made it possible to formulate recommendations for the state industrial policy. In the literature, 'carbon dividend' is referred to as the phenomenon of returning carbon fees to the economy, for example, to the same industry in the form of investments [Li et al., 2023, p. 19085]. It seems expedient to use the term 'dividend' to refer to the result (in the form of savings on the amount of the carbon fee) from the financial and technological efforts mounted by the business.

The objectives of the research are as follows:

1) to evaluate the technological and financial burden of European and Russian large companies caused by adaptation to low-carbon requirements;

2) to reveal the technological achievements of these companies;

3) to compare the results of assessing Russian and European companies, taking into account the risks of underpayment of dividends obtained from the efforts made;

4) to produce recommendations for the implementation of the state industrial policy.

According to the research hypothesis, the EU is considered more successful in reducing the carbon footprint of industries, but the financial and technological burden on the EU business is higher. Moreover, in today's global economic conditions, there is a high probability of underpayment of dividends produced by the efforts undertaken.

The novelty and theoretical significance of the study lies in systematizing technological opportunities and risks of adaptation of Russian and European large businesses to the world economic conditions, which are characterized, in addition to the prospects for the introduction of carbon footprint requirements in the EU, by severe sanction restrictions, as well as in formulating recommendations for state policy in this area.

[1] CBAM. European Commission. https://taxation-customs.ec.europa.eu/green-taxation-0/carbon-border-adjustment-mechanism_en.

[2] EU Carbon Pemits. Trading Economics. https://tradingeconomics.com/commodity/carbon.

THEORETICAL APPROACHES TO ANALYZING CARBON-INDUCED TECHNOLOGICAL CHANGE FOR BUSINESS

Researchers pay special attention to the analysis of the green manufacturing effect [Kumar, Kumar, Sharma, 2022, p. 1107]. Based on the findings presented in the scientific literature, technological effects caused by the requirements to reduce the carbon intensity of production can be systematized as follows.

1. By industry-specific and sectoral characteristics, taking into account particular industries, in which economic entities will be most significantly affected by the introduction of carbon emissions regulations.

1.1. An approach that emphasizes that carbon pricing drives technological progress in non-energy sectors [Chen, 2021, p. 10]. Among vivid examples are the emergence of technology for direct reduced iron's production followed by processing with an electric arc furnace [Yue et al., 2022, p. 18] and the use of flue gases for metal scrap preheating [Diop et al., 2021, p. 47]. The intensity of investment in 'green' R&Ds in the metalworking industry is very high [Li, Ouyang, 2020, p. 24078; Zhao et al., 2021, p. 947; Song et al., 2022, p. 24]. This is what the carbon fee is designed for [Wolf, 2022, p. 734]. Low-carbon standards deal with not just ecology protection, but modernization of the technological order [Yakovlev et al., 2020, p. 867], and, according to Andreeva et al. [2019, p. 584], they can lead to the emergence of new industries.

1.2. Another approach focuses on the fuel and energy complex, for example, the development of fuel cell electric vehicles [Nakanishi, 2021, p. 43]. Traditional energy production also involves carbon reduction technologies, i.e., switching from coal to methane, for example, when increasing the production of methane from coal beds [Zhang, Kolesnik, 2022, pp. 3–4]. Energy enterprises are assessed in terms of energy efficiency economic indicators. These include, for instance, aggregate economic indicators, such as diversification of funding sources, fundraising costs, indicators for assessing energy consumption, reliability, intellectual potential, and environmental protection [He, 2022, p. 7, 20]. At the same time, evaluating the technological load is still an urgent task. The financial and technological burden of the energy transition is due to the following reasons: 1) there are significant capacities of traditional power plants, and they are costly to be re-equipped with H_2 and CO_2 capture technologies [Gaysina, Kharisova, Sharafullina, 2022, p. 30]; 2) many technologies are imported [Bezhan, 2021, p. 453].

2. By costs: how heavy the burden induced by carbon regulations is.

2.1. A number of studies indicate that the production costs of the processing industries will increase insignificantly. This approach is based, among other things, on the lowering renewable energy costs [Kudryavtseva, Serebrennikov, 2022, p. 139]. According to researchers, the payback period of the hydrogen production from steelmaking converter gas at given parameters (11 million tonnes of steel per year) [Petin et al., 2020, p. 7] or non-waste processing of a particular type of coal with carbon capture [Dikhanbaev, Dikhanbaev, 2020, pp. 37–38] ranges between 1–3 years. However, there is little industrial evidence in support of this approach.

2.2. Proponents of the opposite view believe that the profitability of projects to reduce carbon footprint is in question. Research into hydrogen energy is viable, but scaling up green hydrogen technologies is expensive [Belov, 2020, p. 74]. A project for the methanol production via CO_2 hydrogenation is modeled and found to be inefficient or, if benefits are used, marginally profitable [Zakondyrin, 2023, pp. 294, 296]. The time of cheap renewable energy sources (RESs) is running out [Kisova, Kuznetsova, 2020, p. 106; Martynenko, Konopleva, 2022, p. 128]. For companies, the payback period of renewable energy projects [Usova, Velkin, 2018, pp. 46–47] and the financial strain due to low-carbon technologies [Saevarsdottir, Magnusson, Kvande, 2021, pp. 854–856; Paha, 2022, p. 389; Zhang, Zhou, Li, 2023, p. 25812] are high. In a number of industries, reducing carbon emissions is technologically limited [Makarov, Muzychenko, 2021, p. 29; Li et al., 2023, p. 19092]. It was concluded that low-cost carbon capture, utilization and storage technologies and hydrogen production from fossil fuels are most economically viable for China [Chai et al., 2021, p. 1943].

In sum, the literature mainly discusses what, according to the energy transition paradigm, enterprises should strive for, but almost neglects how heavy their burden is. Profitability problems, i.e., financial strain of business entities, are investigated, but studying the technological load is still an urgent issue. There are provided examples of technological solutions for reducing carbon emissions, which show the actual technological load of an average company that uses the corresponding technology. At the same time, it remains relevant to compare the indicated load, which is typical for companies operating in economies with different carbon legislation. The above highlights the importance of our research. Thus, the given study, in addition to existing developments, evaluates and compares the technological load of Russian and European businesses.

MATERIALS AND METHODS

Based on the authors' understanding of dividend as a result (in the form of savings on the amount of the carbon fee) of the financial and technological efforts made by business when adapting to low-carbon requirements, a method for evaluating its components was developed (Fig. 1).

The first component implies achievement evaluation, the second one – cost evaluation, and the third one – risk evaluation. Achievements determine the ability and readiness of companies to cope with the current and possible extra load while performing their functions and new tasks. Quantitative and/or qualitative indicators are

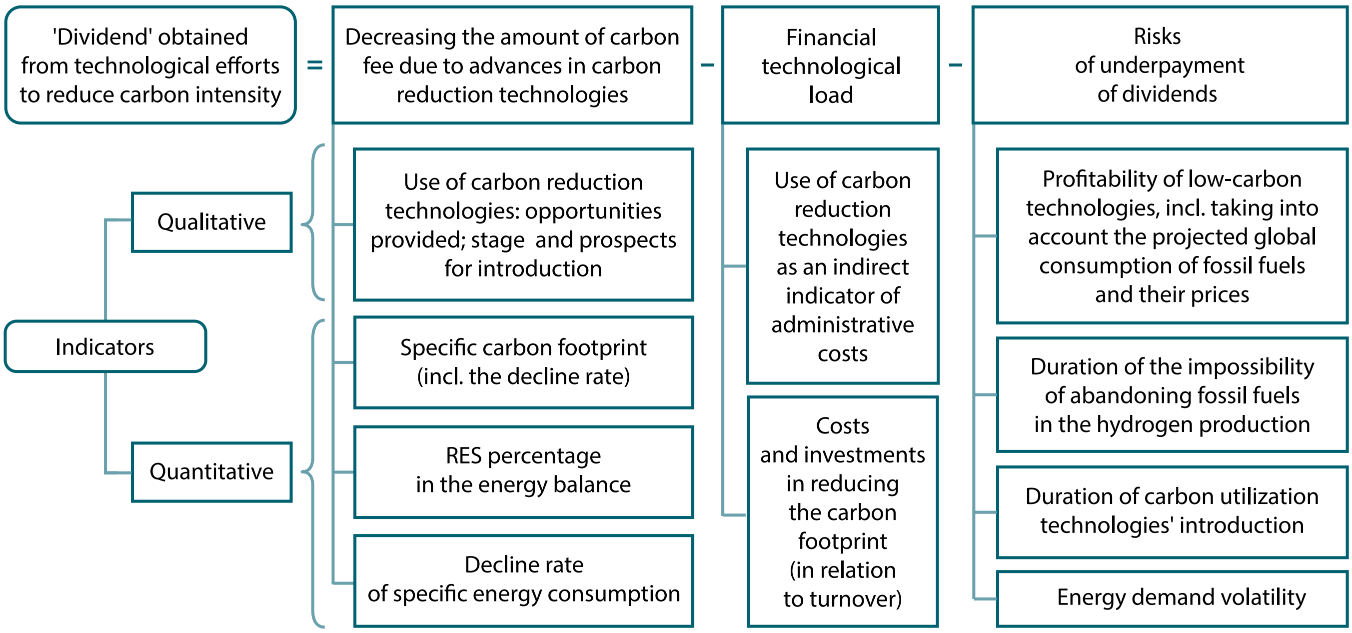

***Fig. 1. Method for evaluating technological efforts to reduce the carbon footprint*[1]**

Рис. 1. Методика оценки технологических усилий по снижению углеродного следа производства

proposed for evaluation. The first two components are assessed using the cases of Russian and European companies. Based on reports from open sources, including ones on sustainable development, the following aspects were analyzed: 1) the progress in reducing the carbon footprint by 2022, when stricter EU sanctions were imposed, which was manifested in the development or introduction of technologies, as well as in the form of indicators of reducing carbon intensity and energy consumption, increasing the percentage of renewables in the energy balance; 2) costs and investments in environmental issues (in relation to the economic turnover).

The third component (risks) was assessed at the macroeconomic level, since the energy transition in the EU was initiated from above – by the national and supranational authorities. The assessment was based on an analysis of the EU economic policy and the overall situation in the global and European energy markets considering energy sources in the EU energy transition plan, EU sanctions, the cost of alternative energy sources, and energy transition difficulties.

Companies were selected for evaluation according to the following criteria: 1) industries for which the EU planned to put the carbon fee (steel, aluminium and energy production); with a special emphasis on metallurgy as having the largest share in Russian exports to the EU; 2) the largest share of the volume of goods produced by the leading producers and exporters and affected by the carbon fee; 3) attention to reducing the carbon intensity in manufacturing: Russian companies are included in the Top-30 in the ESG Ranking (E) as of 15 February 2022[1], i.e., by the time of EU sanctions introduction; of four European companies, two firms are from Germany, which attaches great importance to the energy transition. The sample covered the following companies:

- in the steel industry: (a) in Russia: *Novolipetsk Steel (NLMK)*, the largest Russian steel company[2] ranked 4th in the E-Ranking; *EVRAZ Group*, the world's number-one supplier of rails and a leading manufacturer of steel for the construction industry[3], 23rd in the ranking; and *Magnitogorsk Iron and Steel Works (MMK)*, one of the world's largest steel producers[4], 30th in the ranking; (b) in the European Union: *ThyssenKrupp*, the largest steel company in Germany[5]; and *ArcelorMittal*, the largest steel producer in Europe and the North America[6] headquartered in Luxembourg City;
- in the aluminium industry: (a) in Russia: *RUSAL*, Russia's largest aluminium company[7], 20th in the ranking;

[1] Compiled by the authors based on the analysis of the economic and technological components of the energy transition.

[1] Ranking Russia of ESG Corporate Ranking. Rating Agentur Expert RA GmbH. https://raexpert.eu/esg_corporate_ranking.

[2] NLMK official website. Press releases. https://nlmk.com/ru/media-center/press-releases/nlmk-group-tops-sustainable-development-rating-for-russian-steel-companies. (in Russ.)

[3] EVRAZ Sustainability Report 2021. https://sr2021.evraz.com/download/full-reports/csr_ru_annual-report_pages_evraz_2021.pdf. P. 6. (in Russ.)

[4] Magnitogorsk Iron and Steel Works (MMK). https://mmk.ru/ru/. (in Russ.)

[5] ThyssenKrupp. Geschäftsbericht 2020/2021. https://www.thyssenkrupp.com/de/investoren/berichterstattung-und-publikationen/archiv. S. 67. (in German)

[6] ArcelorMittal. About the company. https://corporate.arcelormittal.com/about.

[7] Milkin V. (2022). How the loss of control over the largest alumina refinery will affect UC Rusal. Vedomosti. April 11. https://www.vedomosti.ru/business/articles/2022/04/11/917643-otrazitsya-uc-rusal. (in Russ.)

(b) in the European Union: *Norsk Hydro*, one of the world's leading aluminium producers; hydroelectric power producer, Norway;

• in the energy industry: (a) in Russia: *RusHydro*, the country's largest power-generating company, including renewable energy sources[1], 13th in the ranking; and *Inter RAO*, a diversified energy company holding a monopoly on the export and import of electricity in Russia[2], ranked 6th in the ESG Ranking; (b) in the European Union: *RWE AG*, a multinational energy company ranked 4th in energy supplies in Germany and Europe's third largest company in renewable energy[3].

The year of 2021 was chosen for analysis as an apogee where the carbon fee was announced and imports from Russia had not yet been restricted.

EUROPEAN AND RUSSIAN BUSINESSES: COMPARATIVE ANALYSIS OF THE FINANCIAL TECHNOLOGICAL LOAD AND ACHIEVEMENTS

The analysis shows that technological and economic efforts of the large companies amid the European carbon paradigm were marked by the following qualitative achievements (Fig. 2).

[1] Annual Report 2021. RusHydro. http://www.rushydro.ru/upload/iblock/b16/Godovoj-otchet-2021.pdf. Pp. 8, 23. (in Russ.)

[2] Ibid. P. 23.

[3] Mittermeier A. GeVestor Financial Publishing Group. https://www.gevestor.de/finanzwissen/oekonomie/rankings/die-4-groessten-energieversorger-in-deutschland-765366.html. (in German)

1. Introduction of technologies:

• capture of carbon dioxide, which is supposed to be used for the production of chemical products (methanol). A qualitative indicator of technological efforts here is the volume of investment;

• injection of coke oven gas into a blast furnace. The steel-producing company ArcelorMittal announced such a project at one of its plants in Spain, which will reduce CO_2 emissions of 125,000 tonnes a year[4]. Attempts to dispose of combustible gases are also made by other companies. In 2021, EVRAZ launched the first four plants in Russian mines that utilized methane-air mixtures at a rate of about 12 m^3/min (capacity of up to 50 m^3/min)[5]. As indicated in the NLMK Annual Report 2021, the use of secondary resources – associated gases from metallurgical production – allows the company to reduce fossil fuels consumption and thus cut greenhouse gas emissions by 3.5 million tonnes of CO_2 a year[6];

• reduction of iron oxides using hydrogen as a reducing agent. This scheme is combined with an electric smelter to produce metal (green steel). As an interim stage on the way to carbon-free steel production, ThyssenKrupp is working to reduce the carbon intensity per tonne of steel

[4] ArcelorMittal. Climate Action Report 2. July 2021. P. 9. https://constructalia.arcelormittal.com/files/Climate_Action_Report_2_July_2021--94aa5d83ef86cd03ec059ef8d1728966.pdf.

[5] Sustainability Report 2021. EVRAZ. P. 51.

[6] Annual Report 2021. NLMK. P. 52.

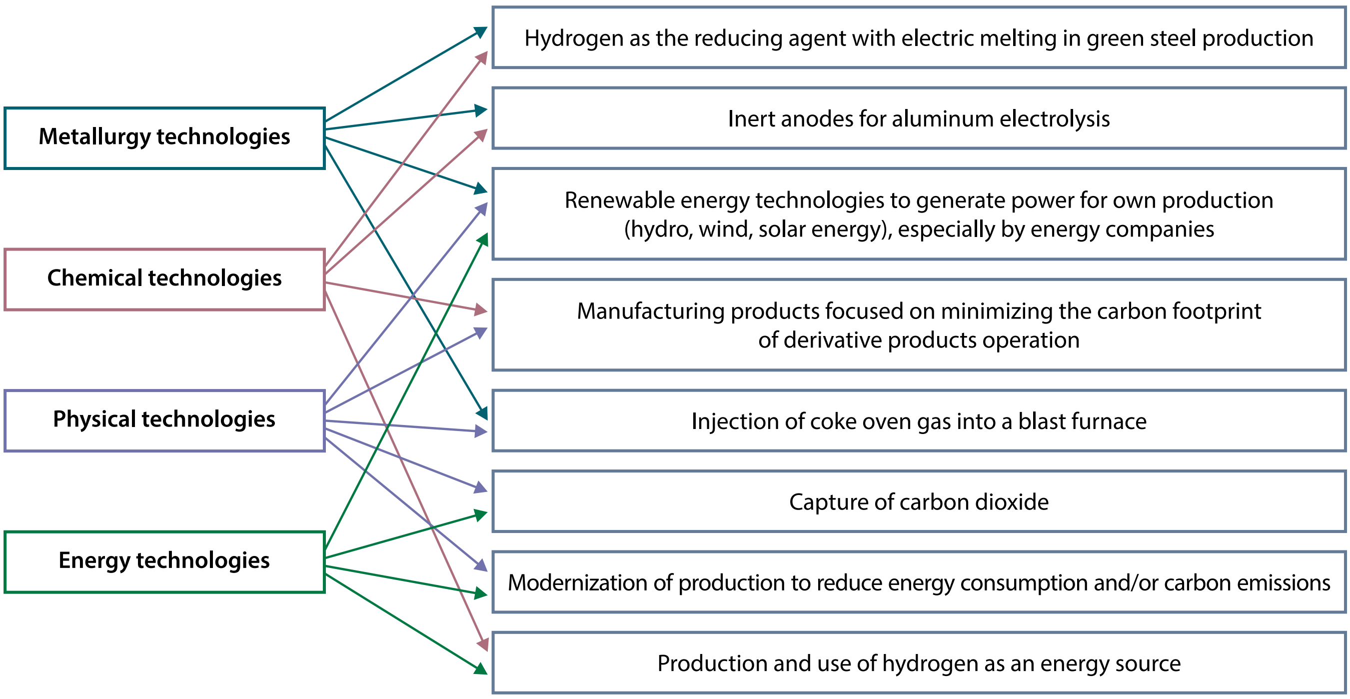

***Fig. 2. Carbon reduction technologies at companies affected by the EU carbon fee*[1]**

Рис. 2. Технологии снижения углеродного следа компаниями, продукция которых затронута углеродным сбором Евросоюза

[1] Based on the analysis of open reports published by the European and Russian companies under review.

by around 70%[1]. ArcelorMittal commissioned technology provider Midrex Technologies to design a demonstration plant in Germany to produce steel with hydrogen. The demonstration plant will produce around 100,000 tonnes of direct reduced iron per year[2]. In Russia, one of the enterprises involved in direct reduction of iron and smelting in electric furnaces is Oskol Electrometallurgical Plant (OEMK)[3];

• other low-carbon metal production technologies. For example, in 2022 Norsk Hydro produced 100 tonnes of recycled aluminium CIRCAL100 from 100% post-consumer scrap with a carbon footprint below 0.5 tonne CO_2 per tonne aluminium[4]. As for Russian companies, they also deliver outstanding results on a global arena. RUSAL commenced testing operations for a pilot industrial electrolytic cell with inert anodes, which has an improved design and a record low carbon footprint (greenhouse gas emissions tend to zero)[5]. NLMK Group implemented investment projects to achieve higher iron content in raw materials, reduce coke consumption, and improve energy efficiency; in 2021, low-carbon nuclear electric energy was purchased[6];

• renewable energy technologies to generate energy for own production needs. ArcelorMittal installed more than 27,000 solar panels on the roof of one of its companies in Belgium[7]. Due to hydropower, RUSAL's aluminium production is characterized by a very high RESs involvement (Table 1, 14R). The energy industry also demonstrates significant achievements (Table 1, 3E, 4R, 4E). The share of wind and solar power sources in the Russian companies' energy balance is lower (Table 1, 3R). On the one hand, it illustrates a tremendous technological and financial strain of the European companies. On the other, the Russian companies also specialize in renewable energy (hydropower), and the RESs percentage in energy consumption is significantly higher than in the EU (Table 1, 4R and 4E);

[1] ThyssenKrupp. Geschäftsbericht 2020/2021. Ss. 92, 95–96. (in German)
[2] Climate Action Report 2. July 2021. ArcelorMittal. P. 7.
[3] Oskol Electrometallurgical Plant (OEMK). Metalloinvest. https://www.metalloinvest.com/business/steel/oemk. (in Russ.)
[4] Annual report 2022. Hydro. P. 90.
[5] Inert anode. RUSAL. https://rusal.ru/innovation/technology/inertnyy-anod. (in Russ.)
[6] Annual Report 2021. NLMK. P. 44.
[7] Climate Action Report 2. July 2021. ArcelorMittal. P. 7.

*Table 1 – Carbon footprint reduction: expenses and technological achievements of the Russian and European companies**
Таблица 1 – Снижение углеродного следа: издержки и технологические достижения российских и европейских компаний

	No.	Russian companies (R)	European companies (E)
Energy production		**Air protection costs**	
	1	Expenses + investments = 1,6% of the economic turnover (Inter RAO)[1)]	Expenses – 5,7% (incl. air protection costs), and investments in wind power installations – 1/8 of external turnover (RWE)[2), 3)] Once free quotas are used up, polluters must pay for CO_2 emission. As of 6 April 2023, the price of EU Carbon Permits equalled 101.25 euros per tonne[12)]
		Technological achievements	
		Specific carbon footprint of production	
	2	In 2019–2021, the carbon footprint of electricity generation decreased by 5.9%, of thermal energy – by 0.3% (RusHydro)[4)]. In 2019–2020, the energy footprint decreased by 4.3% (Inter RAO)[1)]	In 2019–2021, specific CO_2 emissions (by units included in the European Emissions Trading System) fell by 12.3% (RWE)[2)]
		Percentage of non-conventional RESs (excl. hydroelectricity)	
	3	0.3% of electricity generation RusHydro)[4)]	11.7% of electricity sales (RWE)[3)]
		Percentage of all types of RESs in the energy balance	
	4	81.2% (RusHydro)[4)]	28.4% (RWE)[2)]
		Specific energy consumption	
	5	In 2019–2021, fuel consumption for heat generation decreased by 1.3%, electricity – by 1.5% (RusHydro)[4)]	In 2021, a 27.3% reduction was recorded (RWE)[2), 15)]
Steel production		**Carbon reduction expenditures**	
	6	Ratio of environmental projects funding and environmental protection expenditures to consolidated revenue in 2021: 0.7% (EVRAZ)[5)]; ratio of environmental protection expenditures to consolidated revenue: 2.1% in 2021 (NLMK)[7)], 1.5% in 2020 (MMK)[13)]	1. According to ArcelorMittal estimates, based on levels of free allocations from 2019, the approximate annual impact of a EUR5 increase in the price of carbon would be 50 million euros. If the level of free allocations are reduced to zero, the sensitivity to a EUR5 change in the carbon price would increase to over 290 million euros (0.6% of 2020 sales[14)]) per annum[6)]. 2. Once free quotas are used up, polluters must pay for CO_2 emission. As of 6 April 2023, the price of EU Carbon Permits equalled 101.25 euros per tonne[12)]

Table 1 (concluded)
Окончание таблицы 1

	No.	Russian companies (R)	European companies (E)
Steel production		*Incl. costs for CO_2 capture and processing technologies*	
	7	Memorandums were signed with energy companies on the development of CO_2 capture, utilization and storage projects (NLMK)[7)]	The Carbon2Chem project received two grants of 60 and 75 million euros to convert industrial CO_2 emissions into valuable chemical substances with the help of hydrogen (ThyssenKrupp)[8)]
		Technological achievements	
		Specific carbon footprint of production, t CO_2e/t steel	
	8	1.95 in 2021 (MMK)[9)]; 1.90 in 2021 (EVRAZ)[5)]; 1.89 (regional methodology) in 2021 (NLMK)[7)]	1.70 in 2018 (ArcelorMittal production in Europe); in 2020, the average carbon intensity in the company's steel business was 2.08 tonnes of CO_2 per tonne of steel[6)]
		Carbon emissions decline rate	
	9	A 10.6% decline in 2020–2021 (MMK)[9)]; a 3.1% reduction in 2017–2021 (NLMK) (15% in steel production in 2010–2021)[7)]; a 2.1% decline in 2019–2021 (EVRAZ)[5)]	A 7.9% reduction in 2007–2020, incl. a 1.6% improvement over 2019 (ArcelorMittal)[6)]
		RESs percentage in the energy balance	
	10	A rise from 0.36 to 0.43% in 2017–2021, incl. energy consumption – from 4.81% to 5.14% (NLMK)[7)]	Percentage of RESs and recovered energy sources in energy consumption (steel) in 2019 – 44%, in 2020 – 33% (ArcelorMittal)[14)]
		Specific energy consumption	
	11	A 6.4% decrease in 2019–2021 (EVRAZ)[5)]; a 1.6% reduction in steel production in 2017–2021 (NLMK Lipetsk)[7)]	A 1.7% increase in steel production in 2018–2020 (ArcelorMittal)[14)]
Aluminium industry		**Carbon reduction expenditures**	
	12	Atmospheric air protection expenditures in 2021: 0.6% of the economic turnover (RUSAL)[10)]	Once free quotas are used up, polluters must pay for CO_2 emission. As of 6 April 2023, the price of EU Carbon Permits equalled 101.25 euros per tonne[12)]
		Technological achievements	
		Carbon footprint of production, t CO_2e/t products	
	13	Production of low-carbon aluminium (ALLOW brand): 2.4 t[10)] (average carbon footprint across aluminium industry is 12.5 t). A 11.6% decrease across aluminium industry in 2014–2021 (RUSAL)[10)]	Alumina refining: a 20.3% decrease – from 0.79 in 2018 to 0.63 in 2021. Aluminium production (electrolysis): a 2.5% rise – from 1.60 in 2018 to 1.64 in 2021 (Norsk Hydro)[11)]
		RESs percentage in the energy balance	
	14	99.35% (RUSAL)[10)]	41% (Norsk Hydro)[11)]
		Specific energy consumption decline rate	
	15	A 4.2% decline across aluminium industry in 2014–2021 (RUSAL)[10)]	In 2018–2021: alumina refining – a 15.5% decline; aluminium production (electrolysis) – a 0.4% increase (Norsk Hydro)[11)]

(*) the year of 2021, unless otherwise specified.

Source: Based on [1)]Inter RAO Annual Report 2021. Corporate Information Disclosure Center. https://www.e-disclosure.ru/portal/files.aspx?id=12213&type=2. Pp. 81–82, 87, 195. (in Russ.); [2)]Nachhaltigkeitsbericht 2021. RWE. https://www.rwe.com/-/media/RWE/documents/09-verantwortung-nachhaltigkeit/cr-berichte/bericht-2021.pdf. Blatt 2. Ss. 10, 33, 51, 118, 120. (in German); [3)]Geschäftsbericht 2021. RWE. https://www.rwe.com/-/media/RWE/documents/05-investor-relations/finanzkalendar-und-veroeffentlichungen/2021-GJ/2022-03-15-rwe-geschaeftsbericht-2021.pdf?sc_lang=de-DE. Ss. 3, 58, 86. (in German); [4)]RusHydro Annual Report 2021. Pp. 65, 98, 101; [5)]EVRAZ Sustainability Report 2021. Pp. 10, 53, 56, 83; [6)]Climate Action Report 2. July 2021. ArcelorMittal. https://corporate-media.arcelormittal.com/media/ob3lpdom/car_2.pdf. Pp. 44, 49; [7)]NLMK Annual Report 2021. https://nlmk.com/upload/iblock/469/NLMK_AR2021_RUS.pdf. Pp. 7, 44, 51–52, 66, 68, 75. (in Russ.); [8)]Geschäftsbericht 2020/2021. ThyssenKrupp. Ss. 92, 95–96; [9)]Climate Strategy. MMK. https://mmk.ru/ru/sustainability/ecology/climate-strategy. (in Russ.); [10)]RUSAL Sustainability Report 2021. https://rusal.ru/upload/iblock/749/vjb1mj5ndij4neep8pnjervek7bczlpz.pdf. Pp. 34, 54, 65–66, 73, 160. (in Russ.); [11)]Hydro. Annual Report 2022. https://www.hydro.com/Document/Doc/Annual%20Report%202022ENG.pdf?docId=589854. Pp. 215, 217; [12)]EU Carbon Permits. Trading Economics. https://tradingeconomics.com/commodity/carbon; [13)]Ecology. MMK. https://mmk.ru/ru/sustainability/ecology. (in Russ.); [14)]Fact Book 2020. ArcelorMittal. May 2021. https://corporate-media.arcelormittal.com/media/tbob5lrm/factbook-2020.pdf. Pp. 6, 38, 48; [15)]Nachhaltigkeitsbericht 2020. RWE. https://www.rwe.com/-/media/RWE/documents/09-verantwortung-nachhaltigkeit/cr-berichte/bericht-2020.pdf. S. 117. (in German)

- production and use of hydrogen as an energy source: (1) placing electrolysers at the existing large power plants; (2) hydrogen-producing offshore wind turbines; (3) gas-fired power stations able to operate on hydrogen or the methane-hydrogen mixture. In 2021, RWE participated in around 30 green hydrogen projects. Technology (1) is represented by the GET H2 Nukleus project launched in 2020, according to which three electrolysers are to be built at one of the existing power plants by 2026. To implement technology (2), RWE plans to launch two turbines by 2026, and to employ technology (3) – a hydrogen-capable gas turbine at the existing station in 2024[1].

2. *Modernization of production to reduce energy consumption and/or carbon emissions*. In 2021, MMK started the construction of a coke oven battery, which could reduce CO_2 emissions by 1.1 million tonnes[2]. Inter RAO modernized power units of the State Regional Power Plant (GRES), re-equipped feedwater paths of CHP burners and the CHP turbogenerator; in 2019–2021, air protection costs (expenses plus investments) increased 3.5 times. This helped to reduce the specific emissions of greenhouse gas (Tables 1, 2R);

3. *Manufacturing products focused on minimizing the carbon footprint of derivative products operation*. NLMK Group produces steel plates that are used in construction of wind power installations, as well as premium electrical steels that enable consumers to reduce specific magnetic losses in transformers and electrical motors; high-strength and wear-resistant steels, which delivers metal structures of lower weight and leads to lower fuel and steel consumption[3].

The companies' technological achievements are quantitatively expressed in their success in reducing the carbon intensity of production (Table 1, lines 2, 8, 9, 13) and energy consumption (Table 1, lines 5, 11, 15) and in the RESs percentage in the energy balance (Table 1, lines 3, 4, 10, 14). Although in terms of the carbon footprint the European segment of ArcelorMittal is more optimized if compared with Russian steel production, the entire ArcelorMittal group is inferior in terms of the carbon footprint and in its decline rate (Table 1, lines 8, 9). In the aluminium industry, Norsk Hydro demonstrated the optimal carbon footprint in 2021; however, Russian companies also notched up a number of wins, such as low-carbon aluminium brand (sales in 2021 – about 1.0 million tonnes[4]), carbon footprint dynamics (Table 1, 13R), a significantly higher RESs share in the energy balance (Table 1, lines 13–15). As for the energy production, the European companies have made great strides in reducing their carbon footprint, yet the Russian producers are also relatively successful (line 2) and have a higher RESs percentage (line 4). The Russian steel-producing companies showed the better dynamics of specific energy consumption (line 11), but in terms of energy (line 5) and aluminium (line 15) production the European companies were in the lead.

Indirectly, costs (burden) are reflected in the achievements; directly – as the ratio of climate protection expenditures to the economic turnover (Fig. 1). For the Russian companies, the value of this ratio is lower (Table 1, 1R versus 1E, 6R versus 6E(2), 12R versus 12E), with rare exceptions (6R versus 6E(1), but it is a foreign transnational (not only European) company. Since 2005, once free quotas are used up, European polluters must pay for CO_2 emissions (Table 1, 1E). Costs are evidenced by the fact that energy-intensive companies in some EU countries are entitled to receive compensation from the state for 25–75% of indirect 'climate' costs caused by increased electricity prices. On 19 August 2022, the European Commission approved 27.5 billion euros German scheme to compensate energy-intensive companies for indirect emission costs until 2030[5]. In 2021, Norsk Hydro received about NOK 900 million (compensation)[6]. Thus, the load of elevated energy consumption costs is transferred to the state budget. In addition, the costs of developing and introducing low-carbon technologies increase the product price for subsequent consumers in any case.

ENERGY TRANSITION RISK ANALYSIS

The EU leadership in technological achievements in reducing carbon intensity is objectively due to its low endowment with mineral resources. At the same time, a cost-effective energy transition can face significant risks.

1. Costliness of low-carbon energy. In 2020–2021, hydrogen production by water electrolysis (green hydrogen) was almost 3 times more energy-consuming than by methane pyrolysis (turquoise hydrogen)[7], and 5–10 times more than by its steam reforming (grey hydrogen)[8]. Expert assessments are also given in paragraph 2.2 of the literature review.

2. According to its hydrogen strategy, the EU allows producing hydrogen incl. based on fossil fuels[9], and natural gas was planned to be the main production resource in the medium term (10–15 years) [Belov, 2020, p. 74]. But in this case the carbon footprint would not give European companies much of an advantage when calculating carbon charges.

3. The transition to industrial application of low-carbon technologies can be lengthy. For instance, it will take

[1] Geschäftsbericht 2021. RWE. Ss. 27, 32. (in German)
[2] Climate Strategy. MMK.
[3] Annual Report 2021. NLMK. P. 56. (in Russ.)
[4] RUSAL Sustainability Report 2021. Pp. 65–66.

[5] WTO Expertise Center. www.wto.ru/our-blog/evrosoyuz-ne-gotov-otkazatsya-ot-besplatnykh-kvot-i-kompensatsii-kosvennykh-zatrat-na-vybrosy/?lang=ru. (in Russ.)
[6] Annual report 2022. Hydro. P. 148.
[7] Konoplyanik A. (2020). Pure hydrogen from natural gas. Gazprom, no. 9, pp. 20–29. (in Russ.)
[8] TASS. https://tass.ru/ekonomika/11824311. (in Russ.)
[9] A hydrogen strategy for a climate-neutral Europe. https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

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about 15 years until the Carbon2Chem project (ThyssenKrupp) will be applicable on an industrial scale[1].

4. In case of focusing on reindustrialization, the energy consumption of the European economies will be growing. At that, developing states will also build up industry, and, most likely, using traditional energy sources. Won't their industry become more competitive than the European one powered by expensive renewable energy?

While testing this hypothesis, we can analyze the trends and global demand forecast for traditional energy carriers. In 2010–2021, global oil demand increased from 87.2 to 94.5 million barrels/day. Under the Net Zero Emissions by 2050 Scenario (NZE), by 2030, demand is expected to be 86.4% of the 2010 level, and by 2050 – 26.2%. But under the Stated Policies Scenario (STEPS) and the Announced Pledges Scenario (APS), it will remain significant: relative to 2021 – 108.4% and 98.4% in 2030 and 108.8% and 77.1% in 2040 (hereinafter in this section, the calculations results based on the data from Table 2 are given).

The increase in the global natural gas demand in 2010–2021 was even more significant than in oil demand – from 3,329 to 4,213 billion m^3. According to the NZE Scenario, relative to 2010, it will be 98.2% in 2030 and 34.8% in 2050. The STEPS Scenario indicates that, relative to 2021, it will be 103.8% in 2030 and 103.4% in 2050 (i.e. more than in 2021). The APS Scenario projects a 116.4% and 79.9% increase relative to 2010. Thus, even according to the NZE Scenario, demand in 2030 will still be comparable with the 2010 level or even higher as projected in the STEPS and APS.

Between 2010 and 2021, there was also a rise in the global demand for coal – from 5,220 to 5,644 million tonnes of coal equivalent. According to the NZE Scenario, in 2050 it will fall to 10.3% of the 2010 level, but the STEPS and APS Scenarios forecast that in 2030 it will be of the same order as in 2010, i.e., 98.6% and 87.0%, and by 2050 it will decrease to 73.3% and 30.9%.

Such a wide spread of forecast values seems to be indicative of a high uncertainty in the development of the global energy balance. It is also noteworthy that even in the NZE Scenario, global energy consumption by 2030 (398 EJ) will be comparable to the values of 2010 and 2021 (103.9% and 90.7%), and in the STEPS and APS Scenarios, the values will exceed the level of 2021 (110.5% and 102.7%). Thus, by 2030 the world economy will remain in gross absolute terms no less energy-intensive than in 2010, and it will be more energy-intensive as early as 2050, according to STEPS and APS.

The price for oil in 2023 and 2024 is projected to be higher than in 2021 (130.7% and 113.6% of 70.4 US dollars per barrel), as well as for natural gas in the European market (199% and 174% of 16.1 US dollars per million BTU), in the US market (159% and 154% of 3.9 US dollars per million BTU) and the LNG market (157% and 147%

[1] Carbon2Chem. ThyssenKrupp. https://www.thyssenkrupp.com/de/newsroom/content-page-162.html.

Table 2 – Global demand and price on traditional energy sources
Таблица 2 – Мировой спрос и цена на традиционные энергоносители

Demand indicator	2010	2021	Forecast*	2030	2050
Oil, million barrels/day	87.2	94.5	NZE	75.3	22.8
			STEPS	102.4	102.8 (by 2040)
			APS	93.0	72.9 (by 2040)
Natural gas, billion m^3	3 329	4 213	NZE	3268	1 159
			STEPS	4372	4 357
			APS	3874	2 661
Coal, mln tce	5 220	5 664	NZE	NA	540
			STEPS	5149	3 828
			APS	4539	1 613
Energy consumption (incl. renewable), EJ	383	439	NZE	398	337
			STEPS	485	544
			APS	451	433

Price indicator	2021	2023	2024
Crude oil price (Brent), USD per barrel	70.4	92.0	80.0
Natural gas price, USD per mln BTU			
European market	16.1	32.0	28.0
USA market	3.9	6.2	6.0
LNG market (Japan)	10.8	17.0	15.9

*NZE is the Net Zero Emissions by 2050 Scenario; STEPS is the Stated Policies Scenario; APS is the Announced Pledges Scenario.

Source: Based on 1) demand indicators: World energetic outlook 2022. IEA. https://www.iea.org/reports/world-energy-outlook-2022. Pp. 239, 329, 331, 369, 414, 417; 2) price indicators: Commodity Price Forecasts. World Bank. https://thedocs.worldbank.org/en/doc/d8730a829c869c7aeaba547eb72d6b3f-0350012022/related/CMO-October-2022-forecasts.pdf.

of 10.8 US dollars per million BTU). That is, according to forecasts, the world's traditional energy industry will be warming up, and, consequently, developing. Ultimately, this will keep its competitiveness with renewable energy, and hence the competitiveness of industries that use traditional energy sources.

5. A big challenge for the energy transition (for the profitability of its technologies and their sufficiency to cover energy needs) is the situational volatility of energy consumption caused by variability of weather conditions, volatility of economic activity (for example, under the influence of a pandemic), imposition of sanctions, etc. For example, in the winter of 2021, in Japan, there was a sharp spike in electricity prices amid the transition to more environmentally friendly energy sources. In 2022, against the background of restrictions on Russian oil and gas imports to Europe, the contribution of coal to electricity generation increased to 16%. It was decided to restart 26 coal-fired power plant units, which were shut down in 2021. Germany, France, the United Kingdom, the Netherlands, Belgium and Poland postponed the shutdown of nuclear reactors or approved the construction of new ones[1].

Thus, the energy transition is fraught with risks, which can compromise the chance of getting the carbon dividend by the European Union.

DISCUSSION

The above analysis allows us to offer a number of recommendations for state policy to support the technological development of industry (including its environmental friendliness and energy efficiency) and its exports.

1. To protect Russian businesses from high costs of low-carbon technologies and maintain the profitability of Russian exports, it is expedient:

- to monitor carbon policy of third countries (non-EU nations) as buyers of Russian commodities. Due to the European carbon regulations, enterprises in these countries are forced to introduce low-carbon technologies to sell their products in the EU market, which will entail the need to levy an equivalent carbon fee on the foreign suppliers;
- to create a single market with friendly countries (from the EAEU, Asia, Africa, Latin America) regulated by own carbon requirements. This may be attractive to countries with large reserves of coal (e.g., China) and oil (Central Asia, the Persian Gulf, Latin America) that are limited in funds and choose cheap energy sources (i.e., a plenty of emerging economies). This is in line with the trend of developing countries' international integration that can result in an emergence of a common commodity market (regardless of carbon requirements);
- to assist interested companies in separating their production processes considering orders for goods to be exported to friendly countries, where they will be used to manufacture products intended for export to the EU (i.e., the carbon footprint of which will be taken into account), and their production according to the developed low-carbon technologies, and the rest of the commodity mass, which can be manufactured using cheap fuel such as coal and fuel oil.

2. To develop low-carbon energy as a growing component of competition in the international market. Despite the ambiguous prospects for the European energy transition, the achievements of the Russian companies in reducing the carbon footprint are of high practical importance:

- it is possible to save resources and use energy (including non-renewables) with less waste;
- the designed and tested technologies can potentially be implemented by developing partner countries. In addition, it is feasible to continue research in the field of reducing the carbon footprint of coal-fired generation (by capturing carbon dioxide). Such technologies can be employed by partner countries exporting commodities to the EU so as to maintain the attractiveness of Russian coal in terms of the European carbon fee.

Based on the above, it is reasonable:

- to promote cooperation between Russian companies and companies in the EAEU and other friendly countries on developing and introducing hydrogen turbines. Russia produces turbines and entire power plants; in the early 2020s, the country exported turbines for thermal power plants (for example, it completed the modernization of the Mongolian energy system; built, modernized or designed 36 nuclear power units abroad). It may be promising to use them to develop experimental additional production of hydrogen (similar to the RWE technologies). The warm climate in most partner countries can increase the cost-effectiveness of such experiments;
- to analyze the European technological experience (in producing hydrogen and energy from it, using wind and solar power, converting CO_2 into useful substances). It should be taken into account that the production of hydrogen from wind energy in Europe is planned primarily in northern latitudes and using offshore wind turbines. At that, the project profitability should be regarded as the most important aspect.

CONCLUSION

The analysis showed that by the end of 2021 the European and Russian large exporting companies had made efforts to reduce carbon emissions. Among the main developments are the design and/or introduction of technologies for capturing carbon dioxide, injecting coke oven gas into a blast furnace, using hydrogen as a reducing agent with electric smelting to produce green steel, and producing aluminum by electrolysis with inert anodes; renewal and modernization of production facilities to reduce energy consumption and/or carbon emissions; renewable energy technologies to generate energy for own production

[1] The energy crisis brought back to life "dirty" production in Europe. PRIME Economic Information Agency. February 28, 2023. https://1prime.ru/energy/20230228/839928887.html. (in Russ.)

needs (hydro, wind, solar energy), especially by energy companies; technologies for the production and use of hydrogen as an energy source; manufacturing of products that reduce the carbon intensity of derivative products operation.

All the companies under review were successful in reducing the carbon footprint of their production, both in terms of their bottom-line performance and the decline rate. In some cases, the Russian companies were as successful as their European rivals (testing near-carbon-free aluminum production by electrolysis, reducing the carbon footprint of the aluminum industry), and even surpassed them (the percentage of RESs, reducing specific energy consumption in steel production), or showed results above the global average (reduction of specific carbon dioxide emissions in steel production, stimulation of low-carbon aluminum production). The European companies have a smaller carbon footprint in steel production, are more successful in reducing carbon emissions in the energy industry and energy consumption in electricity generation and aluminum production, more consistent in developing technologies for wind and solar power generation, more efficient in the production and use of hydrogen as fuel, the production of green steel, CO_2 capture and processing.

However, costs of the European companies, both technological and financial (relative to the economic turnover), are much more substantial than those of the Russian enterprises, which, as shown above, managed to achieve notable success without even using wind and solar power. Despite the fact that the overall performance of the European companies is more impressive, there are still a number of risks for the EU economy on the way to a cost-effective energy transition: higher traditional energy profitability; duration of low-carbon technologies development; energy market volatility.

Moreover, in a situation where the EU-Russia trade and investment ties have significantly weakened, there is no need for Russian companies to focus on the potential minimization of the planned EU carbon fee. The EU's rejection to import Russian energy resources increases energy supply costs within the Union and impedes the financing of the energy transition by the EU, its particular countries and companies.

The practical significance of the research results comes down to the recommendations for state industrial policy: to protect the Russian business from high costs, it is proposed to create a single market with friendly countries regulated by its own carbon requirements; to assist interested companies in setting up production with no carbon requirements (for products not included in the EU (international) export chain); in terms of the development of low-carbon energy (for goods participating in the chain mentioned) – to promote cooperation between Russian companies and ones from friendly countries on hydrogen turbines; to take into account the European experience in the development of low-carbon production in the northern territories and sea. ■

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